

**ASSESSMENT ON BLOOD FLOW VELOCITY USING
DOPPLER TECHNIQUE FOR CIRCULATORY SYSTEM
DIAGNOSIS AT LEFT VENTRICLE (LV) OF THE HEART**

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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

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FOR CIRCULATORY SYSTEM DIAGNOSIS AT LEFT VENTRICLE (LV) OF THE
HEART**

MUHAMMAD HANIFF BINTI S.M JOHAN

**A dissertation project submitted in partial fulfilment of the requirement for the award
of the degree in Master of Electric Engineering**

**CENTRE FOR GRADUATE STUDIES
UNIVERSITI TUN HUSSEIN ONN MALAYSIA**

JANUARY 2017

Special for:

*Beloved mum and dad,
Puan Rohayati & En. S.M Johan*

*Dearest brothers and sister in law
Capt. Izuwan Hafis TUDM, Khairun Niza and Siti Farhana (FTK UTHM)*

ACKNOWLEDGEMENT

In the name of Allah, The most Gracious and Merciful.

Foremost, I would like to express my sincere gratitude to my advisor Dr. Nabilah Binti Ibrahim and co-advisor Dr. Wan Mahani Hafizah Binti Wan Mahmud for the continuous support of my study, for their patience, motivation, enthusiasm, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor, co-advisor, and mentor for my master study.

Besides my advisor, I would like to thank my lecturer involved indirect; Dr. Audrey Huong, Prof. Madya Dr. Soon Chin Fhong, Prof. Madya Dr. Muhammad Mahadi Bin Abdul Jami and all the electric lecturers as well as the Examination Panels and chairman because they always giving me opinions and advice. Financial support was made possible by the Ministry of Education Malaysia under PTPTN.

I thank my fellow mates: Wan Fatin Liyana, Muhammad Amzar, Lina Farhana, and all my classmates in electric engineering session 2015/2016 and much more for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last one years.

I'm also would like to express my sincere appreciation to my family for nonstop giving me moral support in my study.

May Allah bless you all

ABSTRACT

There are many diseases that related to the left ventricle part in heart. It is because the left ventricle has important responsible for pumping oxygenated blood to tissues all over the body. By using ultrasound machine with pulse wave Doppler can determine the potential of measurement blood flow velocity in left ventricle between the normal and abnormal reading of blood flow. Various conditions may affect the left ventricle and interfere with its proper functioning. The most common are left ventricular hypertrophy, which causes enlargement and hardening of the muscle tissue that makes up the wall of the left ventricle, usually as a result of uncontrolled high blood pressure. So, by assessing the blood flow velocity in the left ventricle will help to detect between normal and abnormal reading blood flow in heart based on the parameter of early diastole. So, this project is trying to assess the parameter of early diastole, E wave (Ew), end diastole, A wave (Aw), Deceleration time (Dct). E/A ratio, E/e' (medial), E/e' (lateral) for the blood flow vector at left ventricle with the assist of the Pulsed Wave (PW) for detection of blood flow circulatory in heart. Based on the parameters that have been focused, all measurement will calculate using ultrasound cursor and tracer. The result was then analyzed based on a few categorizes (Body Mass Index, Smoker and Non-smoker, Exercise and Non-exercise, and Daily diet eating). This study show that result for the blood flow of 'Underweight BMI', 'Normal BMI', 'Non-smoker', 'Regular Exercise', and 'Healthy Diet' have a normal velocity and the pressure filling was normal as it was normal diastolic function compared to other categorizes. Therefore, the measurement of blood flow in left ventricle is very important to detect either the blood flow is normal or abnormal for detection heart disease.

ABSTRAK

Banyak penyakit boleh di kaitkan dengan ventrikel kiri yang sebahagian daripada jantung. Ini kerana, ventrikel kiri penting dalam mengepam darah yang mengandungi oksigen ke seluruh badan. Dengan menggunakan mesin *ultrasound* yakni untuk menggunakan teknik *Pulse Wave Doppler* (PW) membolehkan kebersanan untuk membuat kiraan kelajuan dan pengaliran darah di dalam ventricle kiri dengan mengenalpasti adakah pengaliran darah normal atau tidak normal. Pelbagai situasi yang boleh mengganggu dan menyebabkan keadaan dan fungsi ventikel kiri dari normal. Salah satunya adalah ventrikel kiri *hypertrophy*, yakni kebesaran and ketebalan tisu otot di dinding ventrikel kiri, akan terjadinya tidak terkawal tekan darah tinggi. Jadi dengan menilai tahap kelajuan dan pengaliran darah di ventrikel kiri dapat menolong untuk mengenal pasti antara normal dan tidak normal dalam sesuatu bacaan kelajuan darah di dalam jantung berdasarkan parameter *early diastole*. Dalam projek ini cuba untuk menilai parameter *early diastole*, *E wave* (*Ew*), *end diastole*, *A wave* (*Aw*), *Deceleration time* (*Dct*), *E/A ratio*, *E/e' (medial)*, *E/e' (lateral)* untuk kelajuan darah di ventrikel kiri dengan menggunakan bantuan oleh PW dengan mengesan laluan darah sistem di jantung. Semua pengiraan akan di lakukan dengan menggunakan *ultrasound cursor* dan *tracer*. Keputusan akan dianalisis berdasarkan beberapa kategori (*Body Mass Index*, *Smoker and Non-smoker*, *Exercise and Non-exercise*, dan *Daily diet eating*). Pembelajaran ini menunjukkan bahawa pengaliran dan kelajuan darah 'Underweight BMI', 'Normal BMI', 'Non-smoker', 'Regular Exercise', dan 'Healthy Diet' adalah normal dan tekanan darah mengalir adalah normal yakni normal diastolic fungsi dibandingkan dengan kategori yang lain. Kesimpulanya, pengiraan pengaliran dan kelajuan darah di ventrikel kiri adalah penting untuk di kenal pasti bahawa normal atau tidak normal bagi mengesan penyakit jantung.

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LIST OF SYMBOLS

BMI	Body Mass Index
CDC	The Centers for Disease Control and Prevention
ECG	Electrocardiogram
LV	Left ventricles
PW	Pulse wave
PWD	Pulse wave Doppler
SEM	Standard Error Mean
Aw	A wave velocity
Dct	Deceleration time
Ew	E wave velocity

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CHAPTER 1

INTRODUCTION

1.1 General

Cardiac illness is a major cause of health problems death in the world. Many of the cardiac diseases lead to deformations of the geometry of the heart and thereby also to changes in the quantitative assessment properties of the blood flow in the heart as by Menche (2012).

Blood circulation starts when the heart relaxes between two heartbeats as the blood flows from both atria (the upper two chambers of the heart) into the ventricles (the lower two chambers) which then expand. The following phase is called ejection period, which is when both ventricles pump the blood into the large arteries. In the systemic circulation, the left ventricle pumps oxygen-rich blood into the main artery (aorta). The blood travels from the main artery to larger and smaller arteries into the capillary network. The blood, which is now low in oxygen, is now collected in veins and travels to the right atrium and into the right ventricle.

When the pulmonary circulation starts, the right ventricle pumps blood that carries little oxygen into the pulmonary artery, which branches off into smaller and smaller arteries and capillaries (Menche, 2012). The capillaries form a fine network around the pulmonary vesicles, grape-like air sacs at the end of the airways. Oxygen-rich blood travels through the pulmonary vein and the left atrium into the left ventricle as illustrated in Figure 1.1.

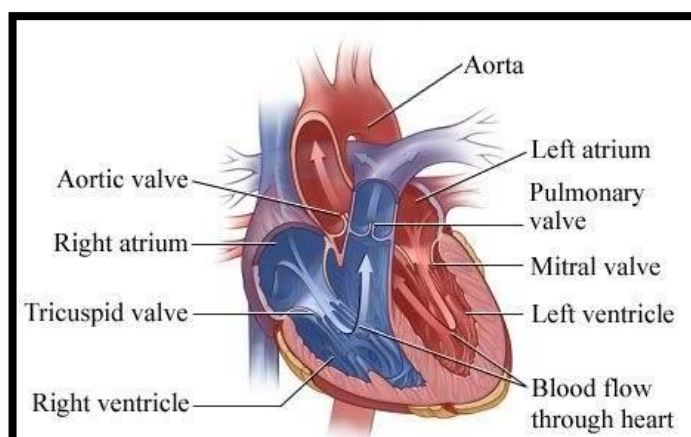


Figure 1.1: The figure of heart structure (Menche, 2012)

The part of the heart that will be a focus on this project is the left ventricle (LV) as indicated in Figure 1.2. Studies carried out by Waleed (2016) and J. Spühler, *et al.* (2012) reported on the left ventricle is located at the bottom left a portion of the heart below the left atrium, separated by the mitral valve. The left ventricle has the thickest wall which responsible for pumping oxygenated blood to tissues all over the body. By contrast, the right ventricle solely pumps blood to the lungs (Thomas, 2014).



Figure 1.2: Heart image using ultrasound indicating the left ventricle (Thomas, 2014)

The Doppler frequency is relied upon in medical field for measuring the blood flow velocity. Pulsed wave (PW) Doppler systems use a transducer that alternates transmission and reception of ultrasound in a way similar to the M-mode transducer as shown in Figure 1.3. PW Doppler was developed because of the need to make localized velocity measurements of turbulent flow (it measures the blood flow velocity

within a small area at a specified tissue depth). It is used to assess ventricular inflow patterns, intracardiac shunts, and to make precise measurements of blood flow at valve orifices.

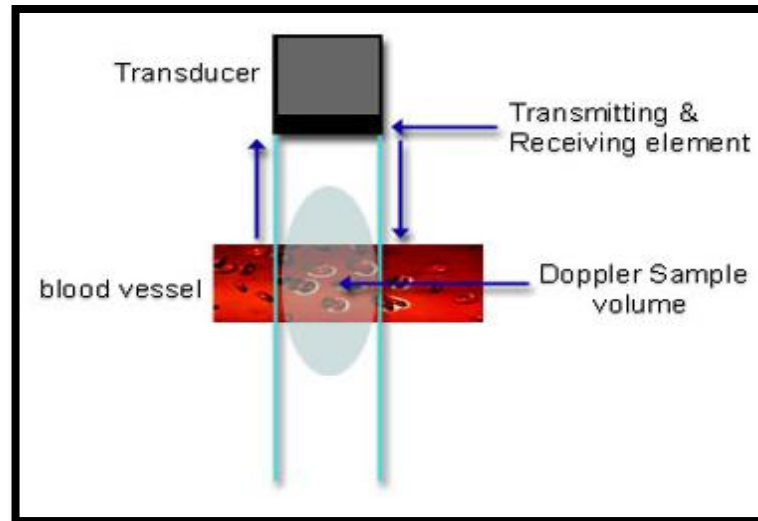


Figure 1.3: Pulsed-wave Doppler transducer (Colin. D, 2009).

In reality, since the speed of sound in body tissues is constant, it is not possible to simultaneously carry on both imaging and Doppler functions at full capability in the same ultrasound system. In mechanical systems as Figure 1.4, the cursor and sample volume are positioned during real-time imaging, and the two-dimensional image is then frozen when the Doppler is activated (Colin. D, 2009).

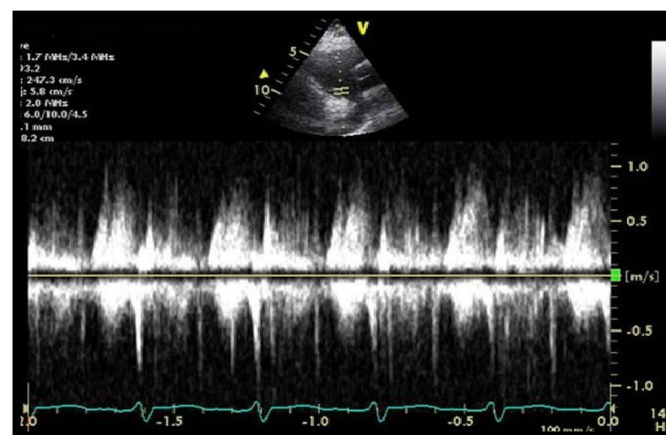


Figure 1.4: When the PW Doppler operates, its show the wave graph of inflow and outflow of blood (Thomas et al., 2014)

1.2 Problem Statement

In medical engineering, simulation on blood flow plays a crucial part in the circulatory system in human body. The circulatory system as part of the left ventricular may have a problem such as hypertrophy disease, thus the patient need to be diagnosed specifically in detail.

Current method that using the Doppler technique did provide the imaging blood flow with presenting of Continuous Wave, PW, and Color Wave. Since left ventricular hypertrophy is enlargement and thickening (hypertrophy) of the heart wall which main pumping chamber (left ventricle), left ventricular hypertrophy can develop in response to some factors such as high blood pressure or a heart condition that causes the left ventricle to work harder. As the workload increases, the muscle tissue in the chamber wall thickens, and sometimes the size of the chamber itself also increases. This situation will produce an abnormal blood flow, with using PW, it can be measured by increment and decrement of blood velocity value, the change in direction flow and presence of turbulence flow. Thus, the goal of this work is to assess the parameter of early diastole, E wave (Ew), end diastole, A wave (Aw), Deceleration time (Dct). E/A ratio, E/e' (medial), E/e' (lateral) for the blood flow vector at left ventricle with the assist of the Pulsed Wave (PW).

1.3 Aim and objective

The ultimate goal of this study is to analyze that blood flow velocity could be more effectively improve the analysis in left ventricle circulatory system with various configurations. The objectives of this research work are:

- a) To perform data collection for quantitative assessment of the blood-flow at left-ventricular of heart with using a different type of group subject.
- b) To assess the parameter of mitral inflow pattern of early diastole “E wave velocity” (Ew), end of diastole “A wave velocity” (Aw), E/A ratio, Deceleration time(Dct), E/e' (medial) and E/e' (lateral).

1.4 Scope of study

This study is an exploratory analysis of the blood flow velocity which involves measurements with the direction of blood at subject in 20-25 years old. The analysis will be conduct with using ultrasound machine on human left ventricle chamber with using PW Doppler mode. The scopes which are focusing on this project are:

- i) 5 healthy and normal Body Mass Index (BMI), 5 underweight BMI and 5 another subject with obese BMI will cooperate.
- ii) 10 normal person for group smoker and non-smoker, 10 normal person for regular and non-regular exercise and 10 normal healthy persons for eating habit.
- iii) The parameters that taken into account are the of early diastole “E wave velocity” (Ew), end of diastole “A wave velocity” (Aw), E/A ratio, Deceleration time(Dct), E/e' (medial) and E/e' (lateral).

1.5 Limitation

There is limitation in this project such are:

- i) Just for the diastolic dysfunction at left ventricle.
- ii) Assumed that, the measurement is good enough be used for the analysis.
- iii) Ultrasound Sonos 5500 Philip was suitable only for scanning heart only.

1.6 Significance of study

The importance of this study is to determine the potential of measurement blood flow velocity in left ventricle between the normal and abnormal reading of blood flow. By having the ultrasound using pulse wave doppler mode to analysis the blood velocity performance in left ventricle because blood is non-Newtonian fluid and to model such fluid is very complicated (J. Labadin, 2006).

Considering the Doppler principle states that the frequency of reflected ultrasound is altered by a moving target, such as red blood cells. The magnitude of this Doppler shift relates to the velocity of the blood cells, whereas the direction of blood flow away and toward from the transducer (Ghaidaa, 2012). Then using the measured

mitral inflow pattern and mitral annulus velocities in this ventricle, the variable was analyzed using “Excel” software, was found that as the velocity of the blood increases and with the blood direction in left ventricle, so does the Doppler frequency and vice versa. The greater the value of the Doppler angle used in the device then the Doppler frequency decreased and vice versa. As well as increasing the transmitted frequency giving an increase in the speed of blood flow and in the Doppler frequency and vice versa.

1.7 Thesis outline

Outline of this dissertation is summarized as follows. **Chapter 1** presents the problem statement, objectives, and scope of the study. **Chapter 2** presents the literature review on the project, which included the background and significance of the blood flow velocity as the part of Doppler mode for the direction of inflow and outflow blood. It also includes reviews on the mitral inflow pattern and mitral annulus velocities.

Chapter 3 presents details of the measurements and tests for collecting data from ultrasound results. **Chapter 4** analyses data and the results mainly from PW mode. The discussions include an assessment of the results obtained. **Chapter 5** presents the conclusions and recommendation for future work.

1.8 Summary

This chapter highlights the general background of this study, including the aims and objectives of the research, followed by an outline of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter embracing the literature review of the project which includes the previous study of left ventricle behavior from B-Mode ultrasound image using Pulse wave Doppler method. The understanding of the left ventricle theory is important to situate the research focus within the context quantitative assessment of the blood flow velocity. It is the knowledge of the disease which allows identifying the gap in this research. This includes the concept, theory, perspective and the method of the project that is used in order to solve the problem occurs and any hypothesis that related with the research of methodology focus.

2.2 Simulation of Blood Flow in the Left Ventricle Using Moving Geometries Based on Ultrasound Measurements (G. A. Khalid, 2012).

This study applies numerical simulation to study such effects of geometry changes on the blood flow in the left ventricle (LV) of the heart. The purpose of such studies is to gain an understanding of the effects of different pathologies and furthermore to possibly study the effects of treatment. There is based on a complete process including patient-specific measurements, automatic geometry modeling based on the measurements, meshing, and simulation of the Navier-Stokes equations. The method used was simulate the blood flow with the incompressible Navier-Stokes equations as expressed in equation (1), using a weighted standard Galerkin/streamline diffusion method.

$$\frac{u + ((u-w)\nabla) u - v \Delta u + \nabla p}{\nabla \cdot u = 0} = f \quad (1)$$

The model geometry of the LV is based on ultrasound measurements during a cardiac cycle of inner wall as the movement of the heart wall during one heart cycle which lasts about one second is not uniform. From these measured points, surface meshes of the chamber are constructed for each sample time. The quantities be used for the evaluation of the model are the mean velocity at the inflow as shown in Figure 2.1 and that outflow shown in Figure 2.2. The mean velocity at the inflow is mainly given by the prescribed inflow profile and that the calculation of the discrete pressure corresponds to the Poisson equation.

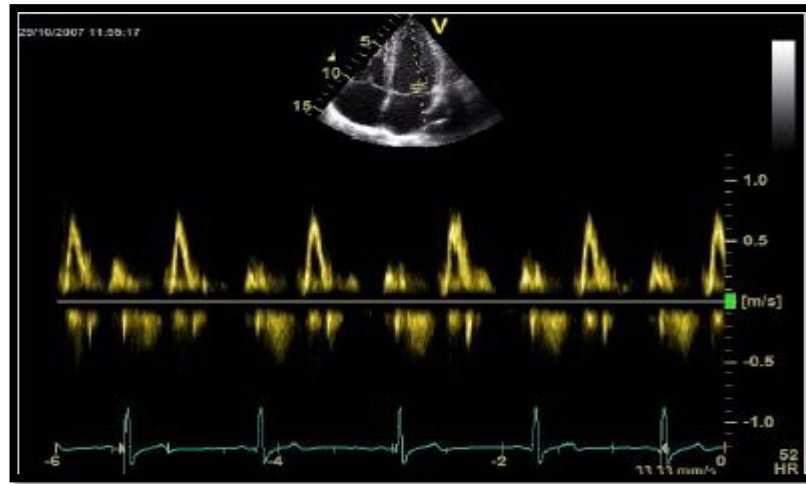


Figure 2.1: Inflow velocity based on ultrasound measurements (G. A. Khalid, 2012)

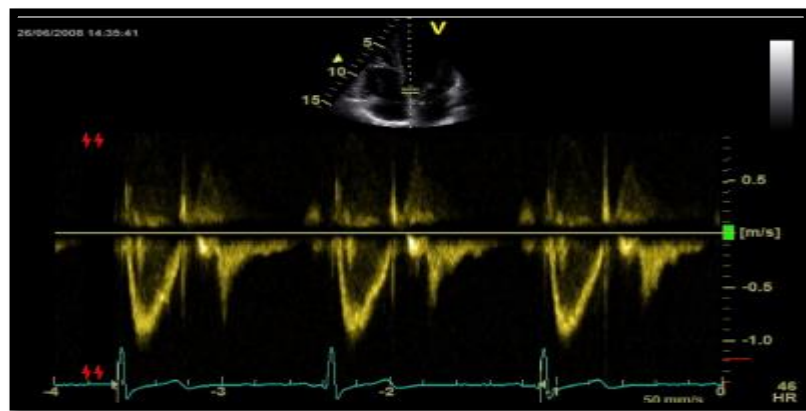


Figure 2.2: Outflow velocity based on ultrasound measurements (G. A. Khalid, 2012)

2.3 Principles of Doppler Echocardiography and The Doppler Examination (Joseph A. K. & David B. A., 2014).

Pulsed wave (PW) Doppler systems use a transducer that alternates transmission and reception of ultrasound in a way similar to the M-mode transducer as shown in Figure 2.3. One main advantage of pulsed Doppler is its ability to provide Doppler shift data selectively from a small segment of the ultrasound beam, referred to as the "sample volume". The location of the sample volume is operator controlled.

An ultrasound pulse is transmitted into the tissues travels for a given time (time X) until it is reflected back by a moving red cell. It then returns to the transducer over the same time interval but at a shifted frequency. The total transit time to and from the area is $2X$. Since the speed of ultrasound in the tissues is constant, there is a simple relationship between roundtrip travel time and the location of the sample volume relative to the transducer face (i.e., distance to sample volume equals ultrasound speed divided by round trip travel time). This process is alternately repeated through many transmit-receive cycles each second.

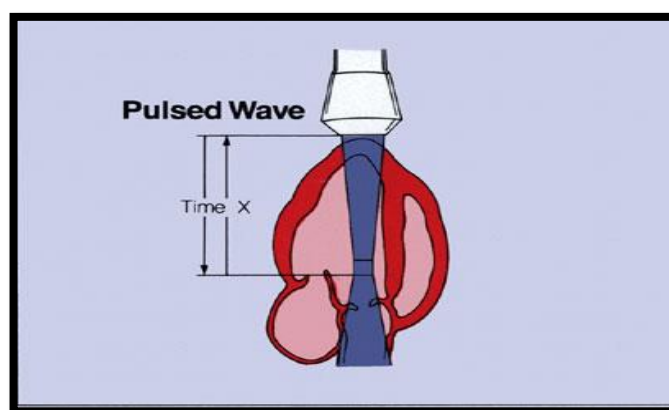


Figure 2.3: In PW Doppler, the transducer alternately transmits and received the ultrasound data to a sample volume. This is also known as range-gated Doppler (Joseph A. K. & David B. A., 2014)

In reality, since the speed of sound in body tissues is constant, it is not possible to simultaneously carry on both imaging and Doppler functions at full capability in the same ultrasound system. In mechanical systems, the cursor and sample volume are positioned during real-time imaging, and the two-dimensional image is then frozen when the Doppler is activated.

With most phased array imaging systems, the Doppler is variably programmed to allow periodic update of a single frame two-dimensional image every few beats as illustrated in Figure 2.4 (Joseph A. K. & David B. A., 2014). In other phased arrays, two-dimensional frame rate and line density are significantly decreased to allow enough time for the PW Doppler to sample effectively. This latter arrangement gives the appearance of near simultaneity.

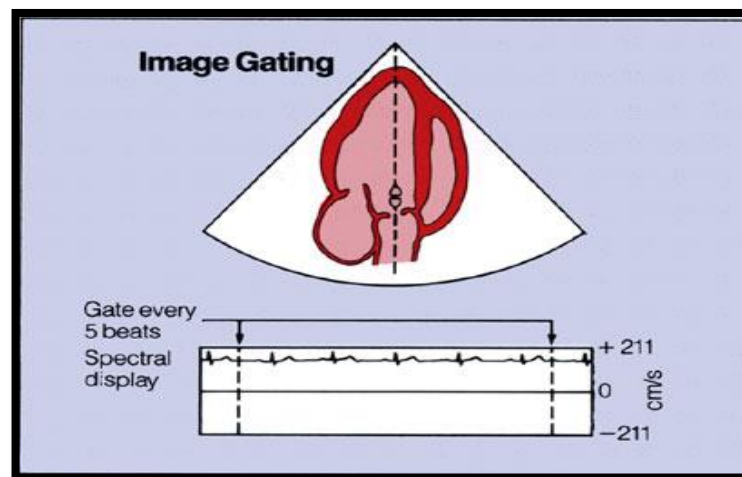


Figure 2.4: When the PW Doppler operates, it causes the two-dimensional image to be held in a frozen frame (Joseph A. K. & David B. A., 2014).

2.4 Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography (Sherif F. N. *et al*, 2009).

The primary measurements of mitral inflow include the peak early filling (E-wave) and late diastolic filling (A-wave) velocities in Figure 2.5, the E/A ratio, deceleration time (DT) of early filling velocity, and the IVRT, derived by placing the cursor of CW Doppler in the left ventricle (LV) outflow tract to simultaneously display the end of aortic ejection and the onset of mitral inflow. Secondary measurements include mitral A-wave duration (obtained at the level of the mitral annulus), diastolic filling time, the A-wave velocity-time integral, and the total mitral inflow velocity-time integral (and thus the atrial filling fraction) with the sample volume at the level of the mitral annulus.

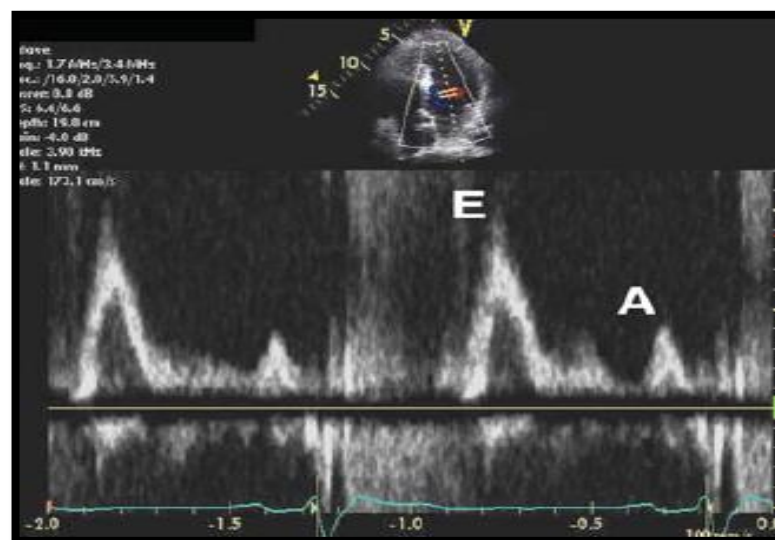


Figure 2.5: The Normal mitral inflow pattern acquired by PW Doppler
(Sherif F. N. *et al*, 2009)

Age is a primary consideration when defining the normal value of mitral inflow velocities and time intervals. With increasing age, the mitral E velocity and E/A ratio decreased, whereas DT and A velocity increase. Normal values are shown in Figure 2.6. A number of variables other than LV diastolic function and filling pressures affect mitral inflow, including heart rate and rhythm, PR interval, cardiac output, mitral annular size, and LA function. Age-related changes in diastolic function parameters

may represent a slowing of myocardial relaxation, which predisposes older individuals to the development of diastolic heart failure.

Measurement	Age group (y)			
	16-20	21-40	41-60	>60
IVRT (ms)	50 ± 9(32-68)	67 ± 8(51-83)	74 ± 7(60-88)	87 ± 7(73-101)
E/A ratio	1.88 ± 0.45(0.98-2.78)	1.53 ± 0.40(0.73-2.33)	1.28 ± 0.25(0.78-1.78)	0.96 ± 0.18(0.6-1.32)
DT (ms)	142 ± 19(104-180)	166 ± 14(138-194)	181 ± 19(143-219)	200 ± 29(142-258)
A duration (ms)	113 ± 17(79-147)	127 ± 13(101-153)	133 ± 13(107-159)	138 ± 19(100-176)
PV S/D ratio	0.82 ± 0.18(0.46-1.18)	0.98 ± 0.32(0.34-1.62)	1.21 ± 0.2(0.81-1.61)	1.39 ± 0.47(0.45-2.33)
PV Ar (cm/s)	16 ± 10(1-36)	21 ± 8(5-37)	23 ± 3(17-29)	25 ± 9(11-39)
PV Ar duration (ms)	66 ± 39(1-144)	96 ± 33(30-162)	112 ± 15(82-142)	113 ± 30(53-173)
Septal é (cm/s)	14.9 ± 2.4(10.1-19.7)	15.5 ± 2.7(10.1-20.9)	12.2 ± 2.3(7.6-16.8)	10.4 ± 2.1(6.2-14.6)
Septal é/á ratio	2.4*	1.6 ± 0.5(0.6-2.6)	1.1 ± 0.3(0.5-1.7)	0.85 ± 0.2(0.45-1.25)
Lateral é (cm/s)	20.6 ± 3.8(13-28.2)	19.8 ± 2.9(14-25.6)	16.1 ± 2.3(11.5-20.7)	12.9 ± 3.5(5.9-19.9)
Lateral é/á ratio	3.1*	1.9 ± 0.6(0.7-3.1)	1.5 ± 0.5(0.5-2.5)	0.9 ± 0.4(0.1-1.7)

Figure 2.6: The table of normal value for Doppler-derived diastolic measurement (Sherif F. N. et al, 2009)

Mitral inflow patterns are identified by the mitral E/A ratio and DT as Figure 2.6. They include normal, impaired LV relaxation, pseudonormal LV filling (PNF), and restrictive LV filling. The determination of PNF may be difficult by mitral inflow velocities alone. Additionally, less typical patterns are sometimes observed, such as the triphasic mitral flow velocity flow pattern. The most abnormal diastolic physiology and LV filling pattern variants are frequently seen in elderly patients with severe and long-standing hypertension or patients with hypertrophic cardiomyopathy. It is well established that the mitral E-wave velocity primarily reflects the LA-LV pressure gradient during early diastole and is therefore affected by preload and alterations in LV relaxation. The mitral A-wave velocity reflects the LA-LV pressure gradient during late diastole, which is affected by LV compliance and LA contractile function. E-wave DT is influenced by LV relaxation, LV diastolic pressures following mitral valve opening, and LV compliance (ie, the relationship between LV pressure and volume). Alterations in LV end-systolic and/or end-diastolic volumes, LV elastic recoil, and/or LV diastolic pressures directly affect the mitral inflow velocities (ie, E wave) and time intervals (ie, DT and IVRT).

2.5 The P, QRS, and T waves in ECG signal (Rangaraj, 2015).

The P wave, QRS complex, and the T wave represent electrical activity in the heart on an electrocardiogram (ECG). The ECG signal could be defined as the PQRST waves as shown in Figure 2.7. The P-Wave represents atrial depolarization as the time necessary for an electrical impulse from the sinoatrial (SA) node to spread throughout the atrial musculature. QRS complex shows the contraction of both ventricles and also reflects the completion of cardiac depolarization and repolarization of atria. P-R Interval represents the time it takes an impulse to travel from the atria to the AV node, a bundle of His, and bundle branches to the Purkinje fibers.

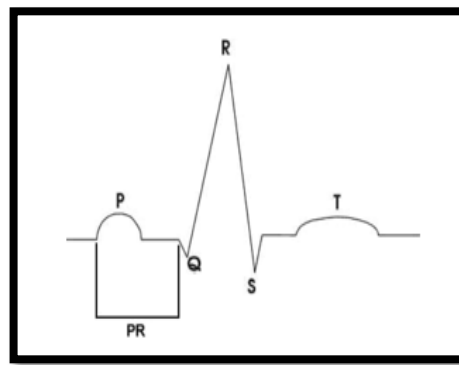


Figure 2.7: The PQRST wave (Rangaraj, 2015)

The QRS wave represents ventricular depolarization, which the condition is a simultaneous contraction of the entire ventricular musculature have 1 mV amplitude and 80 until 100 ms duration. The ST segment represents the end of the ventricular depolarization and the beginning of ventricular repolarization at duration between 100 until 120 ms. The T wave was the repolarization of the ventricles as during ventricular relaxing. The amplitude within the range of 0.1 and 0.3 mV and duration between 120 and 160 ms.

2.6 Summary of literature review

In this chapter, the author thought to understand more about the terms and definition and the concept of principle Pulsed Wave Doppler (PWD), parameter, the technique to make a quantitative assessment of PWD in left ventricle and blood flow velocity. All of the words describe above are related to each other.

PWD is one of the most significance technique to make a measurement of blood flow in the left ventricle. It alternates transmission and reception of ultrasound in the 2D image as using M-mode technique. The PWD is variably programmed to allow periodic update of a single frame two-dimensional image every few beats. In other phased arrays, two-dimensional frame rate and line density are significantly decreased to allow enough time for the PW Doppler to sample effectively.

The assessment will be having an E wave, A wave, E/A ratio, Deceleration time, E/e' medial and E/e' lateral. It significantly contains mitral inflow pattern and mitral annulus velocities. It is apparent that blood flow velocity has a relationship with the mitral valve as have the systolic and diastolic pressure. This study has examined the potential of inflow velocities and outflow velocities of blood in the left ventricle.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The part that is focused in diagnosing blood flow is in left ventricular of the heart. The ultrasound machine with the Pulse Wave Doppler (PWD) setting was employed to achieve the objective.



Figure 3.1: Scan by using Sector probe

For image scanning, sector probe was used that specialized for a cardiac image for an ultrasound as shown Figure 3.1. The image from ultrasound was freeze and will take the data from the PWD of E wave velocity, A wave velocity, Deceleration time, E' medial mitral annulus and E' lateral mitral annulus.

3.1.1 The overall of project flow

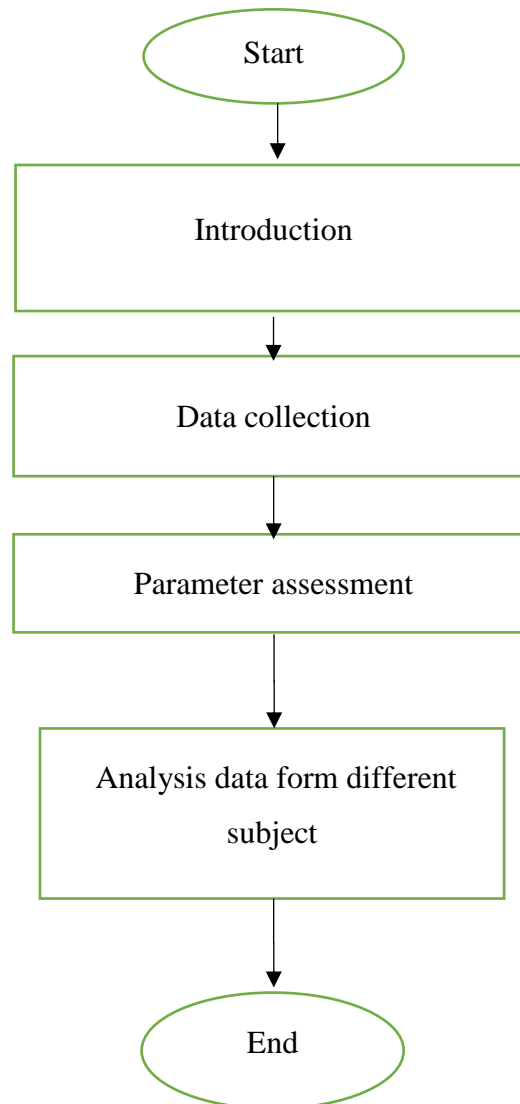


Figure 3.2: Flowchart of the overall project

From the flow chart, Figure 3.2 shown above. The introduction was the starting of the method after that was data collection, mean that the technique of scanning and measure the PW wave. For the parameter, the assessment was for to calculate the early diastole, E wave (Ew), end diastole, A wave (Aw), Deceleration time (Dct). E/A ratio, E/e' (medial), E/e' (lateral). The analysis was to find the difference between the reading of different type subject with comparing the data with find the classified each type of the Class diastolic dysfunction.

3.2 Data collection

3.2.1 The technique of scanning using ultrasound

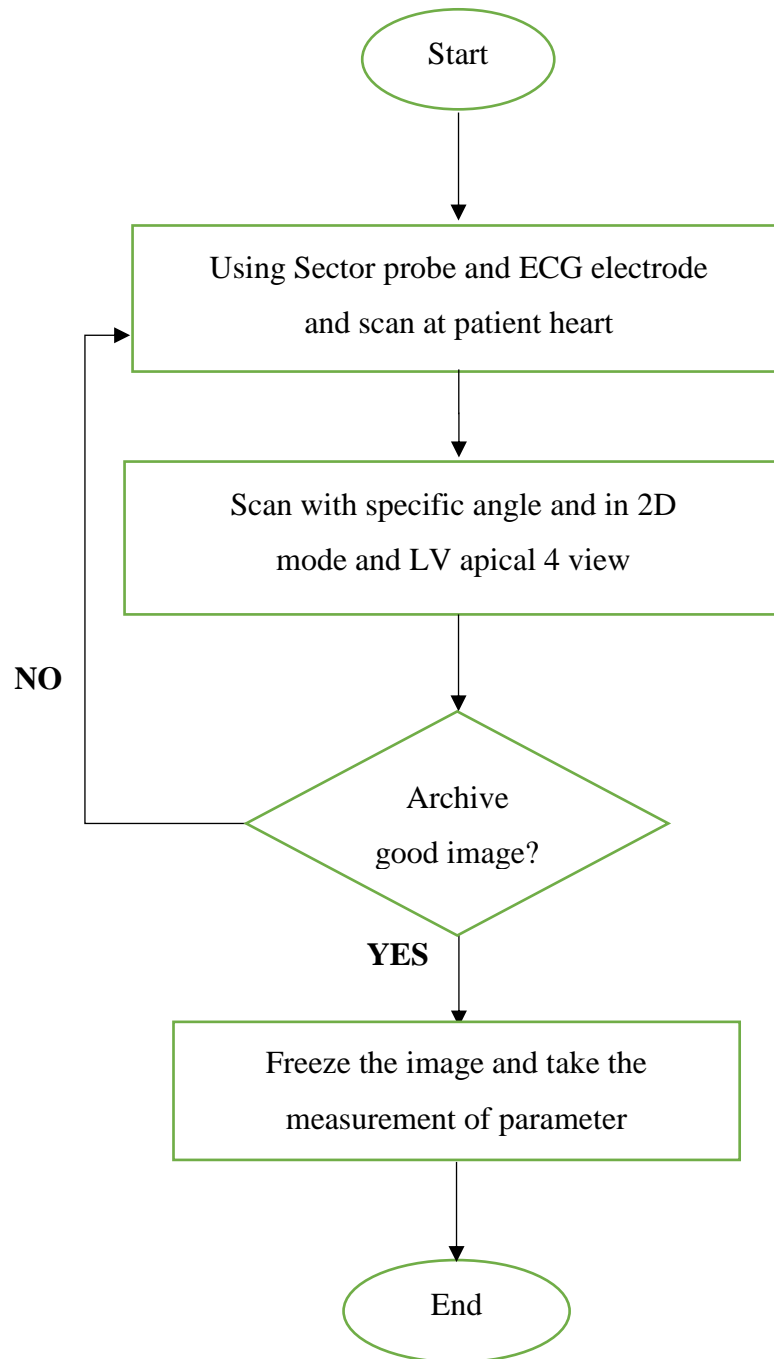


Figure 3.3: Flowchart of the Ultrasound machine method

Figure 3.3 shows the flowchart of scanning techniques. The probe will attach with ultrasonic gel to obtain a clear image. After that, the heart position at the bad is scanned to find the image of left ventricular by using 2D mode at apical 4 views. Then Pulse-wave Doppler imaging mode is used for the value of E wave, A wave, E/e' (medial) and E/e' (lateral).

3.2.2 The scanning method

This project focuses on the apical view of heart for scanning. The view scanning gives 4 chamber images which the apical view is the cut planes of the four-chamber view with and without foreshortening.

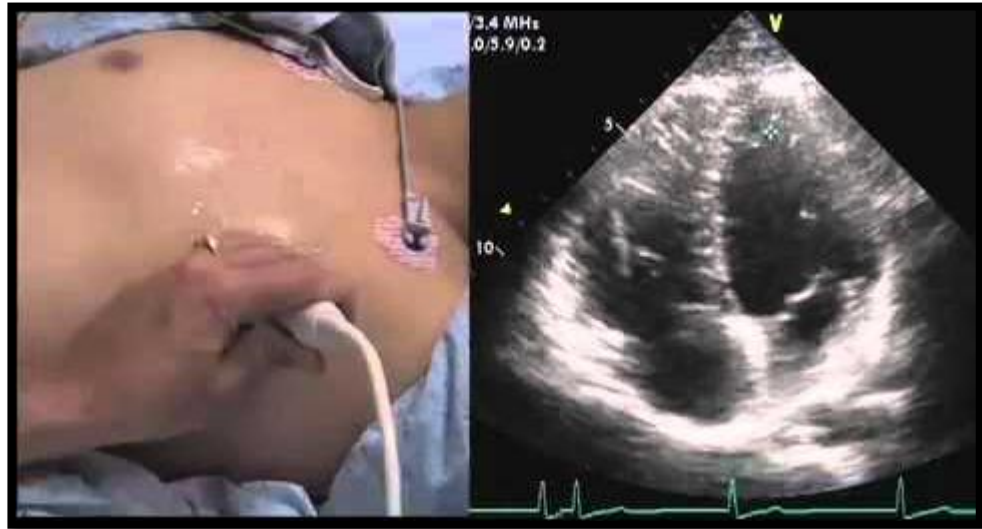


Figure 3.4: The apical view of 4 chamber

$$Doppler\ frequency(fd) = \frac{2.ft.v.cos\theta}{c} \quad (2)$$

ft = transmitted beam

v = velocity of red blood cell

c = speed of sound in tissue (1540)

θ = angle of incidence between ultrasound beam and the direction of the flow

3.3 Parameter assessment

An initial rush of blood as soon as the valve opens causes a peaking of velocity in early diastole, the E wave velocity as Figure 3.5. This is followed by a period of flow or no flow, also known as diastasis. In end-diastole, atrial contraction produces a final rush of blood into the ventricle, the A wave. While these waves can be analyzed by studying the movement of the anterior mitral leaflet in M-mode, it is best done with Pulsed wave Doppler.

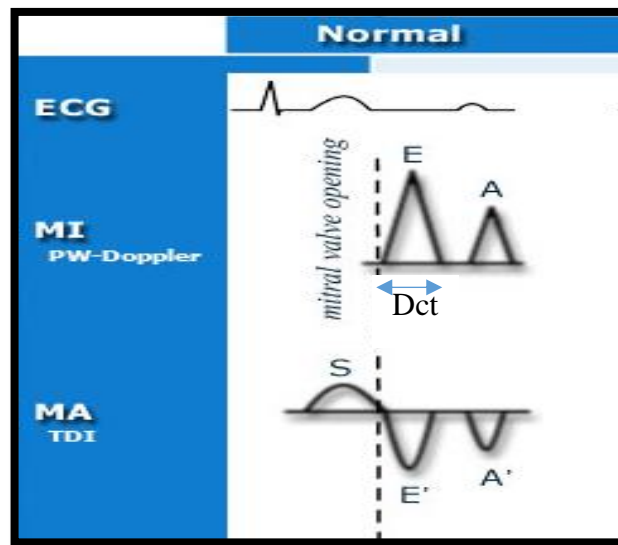


Figure 3.5: The example wave of mitral inflow and mitral annulus velocities (Aurich M, et al 2016)

Many different indices have been used to describe the shape of flow waveforms. The mitral inflow pattern and mitral annulus velocities parameter was based as below:

- Early diastole, E wave (Ew).
- End-diastole, A wave (Aw).
- Deceleration time (Dct) normal value was between 160 - 240ms.
- E/A ratio normal value was between 1-2.
- E/e' (medial) normal value was < 8.
- E/e' (lateral) normal value was <5.

Table 3.1: Category grading for diastolic dysfunction

Type of Class	Grading of ventricular diastolic dysfunction	Condition E/A ratio, Dct and E/e' ratio
Class I	Normal diastolic function	(E > A), Dct in between 160-240 ms and E/e' medial <8 and E/e' lateral <5
Class II	Impaired relaxation	(E:A reversal i.e. E is < A), Dct is (>240ms) and E/e' medial >15
Class III	Pseudonormal	(E:A ratio appears normal), Dct between 160 and 240ms and E/e' medial >15
Class IV	Restrictive filling	(E:A ratio often > 2), Dct is < 160ms and E/e' ratio >15 at the medial annulus

The E/A ratio was for categorizes the subject result after measurement at left ventricle early diastole 'E' and late diastole 'A' as Table 3.1. The meaning of Class II 'impaired relaxation' was usually is related to chronic hypertension or ischemic heart disease. Class III 'Pseudonormal' was mean these patients more commonly have symptoms of heart failure, and many have left atrial enlargement due to the elevated pressures in the left heart. Class IV 'The restrictive filling' was patients tend to have advanced heart failure symptoms "reversible restrictive diastolic dysfunction" and "fixed restrictive diastolic dysfunction"(Paulus WJ *et,al* 2007).

3.4 Analysis using mean, standard deviation and standard mean error

The data result will show in (mean \pm SEM) as the mean value from the average of each type of subject. As the subject was n=5 at each type of subject. Mean as equation(3), Standard of deviation use equation (4) and Standard error mean (SEM) in equation (5) was gain by using the formula as below:

$$mean = \frac{Total\ of\ subject}{number\ of\ subject\ (n)} \quad (3)$$

$$Standard\ of\ deviation = \sqrt{\frac{\sum (each\ value\ of\ data\ set - mean)^2}{number\ of\ subject\ (n)}} \quad (4)$$

$$Standard\ error\ mean(SEM) = \frac{Standard\ of\ deviation}{\sqrt{number\ of\ subject\ (n)}} \quad (5)$$

3.5 Type of subject

3.5.1 Body mass index (BMI)

Before scanning on the subject, the BMI value was measured and follow the Table 3.2. There is 15 subjects with aged between 20-26 years old will be undergoing. Calculation of BMI (6) as follow:

$$\text{Body Mass Index: } \frac{Weight(kg)}{Height(m^2)} \quad (6)$$

Table 3.2: Category of Body Mass Index

Category	BMI
Underweight	Less than 18.5
Normal	18.5 – 24.9
Obesity	Greater than 25

3.5.2 Smoker and non-smoker

The reason for this type of subject because of smoking cigarettes raises heart rate and reduces circulation. The American Heart Association lists the risk for high cholesterol, high blood pressure, heart attack, stroke, peripheral artery disease and aneurysm as higher in smoking vs. nonsmoking adults. The Centers for Disease Control and Prevention (CDC) reports that secondhand smoke raises nonsmokers' risks for coronary heart disease as well. There will 10 subject for this parameter. 5 subject smoker and 5 subject was nonsmoker will be examined and take the data from them.

3.5.3 Exercise and non-regular exercise

Heart is a muscle and needs exercise to stay in shape. When it's exercised, the heart can pump more blood through the body and continue working at optimal efficiency with little strain. This will likely help it to stay healthy longer. Regular exercise also helps to keep arteries and other blood vessels flexible, ensuring good blood flow and normal blood pressure and cholesterol. That why need to find are there have any different blood flow velocity between person that regular exercises compare with subject that non-regular exercise. There will 10 subject for this parameter. 5 subject regular exercise and 5 subject was nonregular exercise.

3.5.4 Daily diet eating

This was to make comparison between subject that have healthy diet eating with subject that not take a diet eating such eat more sugar and junk food and fast food only. The reason was because, diet is one of the key things can change that will impact all other cardiovascular risk factor. There will 10 subject for this parameter. 5 subject have a healthy diet and 5 subject was non-healthy eating diet.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The results are expected the quantitative blood inflow and outflow velocity of left ventricular heart associated the ECG signal. The Excel as the analysis software is used to obtain the value of between the mitral inflow pattern and mitral annulus velocities with image left ventricle, and the image from ultrasound will be through Pulsed Wave Doppler (PWD). Preliminary in this project, the ultrasound machine will be used for scanning the left ventricular to obtain the e/a ratio, Deceleration time (Dct), e' medial and e' lateral. As shown in Figure 4.1 and 4.2, the example image of left ventricular is recorded from the ultrasound machine SONOS 5500 Philip.



Figure 4.1: The image obtained from ultrasound machine SONOS 5500 Philip

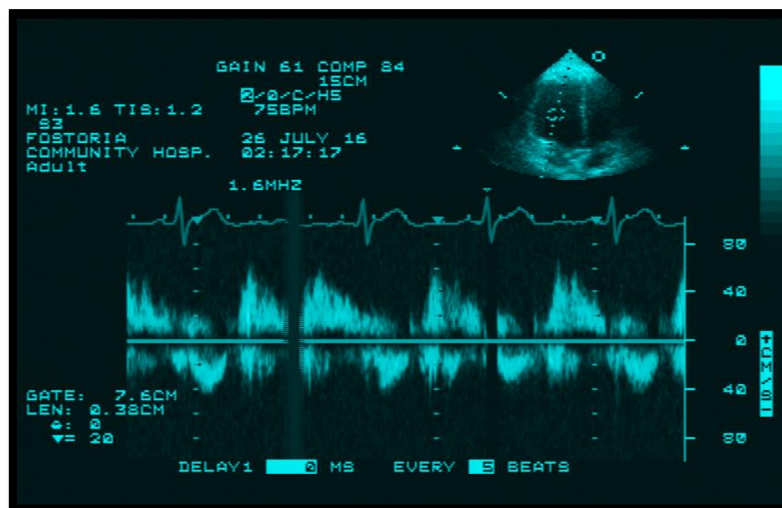


Figure 4.2: The image when using the pulse wave Doppler mode

4.2 The reading when data collection

4.2.1 Taking E wave, A wave and deceleration time

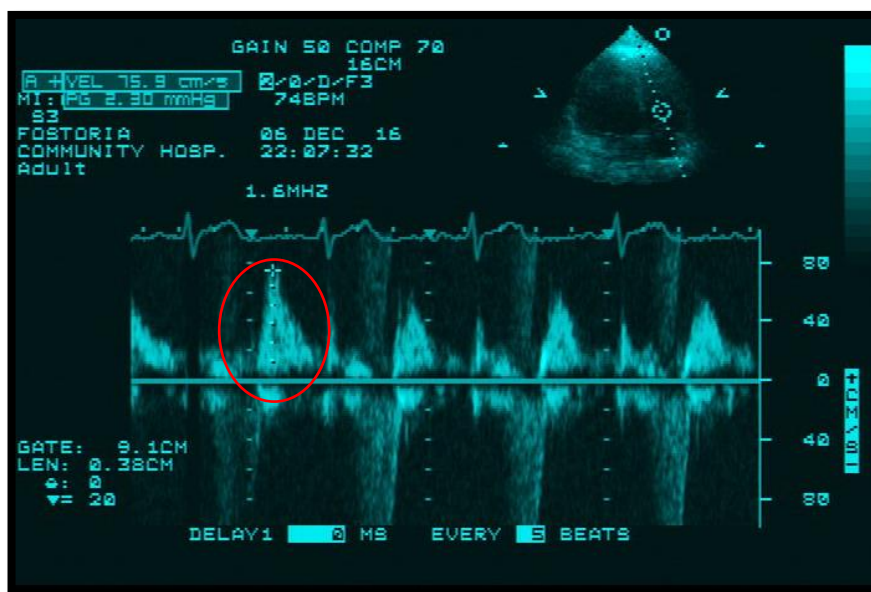


Figure 4.3: The measurement of E wave velocity of LV

Obtain the mitral inflow wave pattern on PWD and freeze the image. After selecting "E" under "mitral valve" in the calculations menu, the height of the E wave is measured as red circle to get the E velocity Figure 4.3. Similarly, the A wave velocity is also measured Figure 4.4. The E/A ratio will be calculated by the manual.

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